URBAN DECAY AND MOSQUITO PRODUCTION IN WEST BALTIMORE: ROOFLESS ABANDONED BUILDINGS AS POTENTIAL OVIPOSITION SITES AND MARKERS OF URBAN DECAY

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Abstract. Due to their role as pest species and vectors of disease, mosquitoes play an important role in decisions regarding public health and in mosquito control and management efforts. Despite this fact, factors governing mosquito production in highly urbanized matrices remain largely unknown. A number of mosquito species have been shown to thrive in human-created habitats such as containers, sewers, and catch basins, yet there is still little information on the mechanisms by which the physical environment alters mosquito abundance and species composition. Even less attention has been paid to the impact of urban decay on mosquito ecology. I examined the effect of roofless abandoned buildings and urban decay on mosquito production in Baltimore, Maryland. Blocks within the highly impoverished Franklin Square neighborhood and slightly higher-income Union Square neighborhood were sampled for adult mosquitoes during four nights of trapping in late July and early August 2012. Though preliminary larval sampling within the neighborhoods suggested that abandoned buildings and decay played a role in mosquito production, findings from the adult trapping showed more mosquitoes within the Union Square block, which contained a lower level of roofless abandoned buildings. Further, these results suggest that other landscape factors may play a more important role in determining mosquito abundance in urban areas.

INTRODUCTION

The presence of disease vectors and invasive species within urban areas are closely intertwined topics that can directly affect processes of human settlement and urban development. In particular, mosquitoes in the United States are pest species that have continuously affected patterns of human behavior and settlement throughout history (Spielman and D'antonio 2001). Although there has been a fair amount of attention paid to the effect of increasing levels of urbanization on mosquito prevalence, less attention has been paid to the effect of urban decay on mosquito ecology. In Baltimore, and throughout the United States, urban deterioration has been largely caused by the disappearance of blue-collar industrial jobs and the flight of the middle-class to the suburbs (Andersen 2003). This process of decay tends to be exacerbated by itself, causing increasing inequities in social, economic, and environmental conditions (Wilson 1996).

Baltimore currently has about a 21% poverty rate, which is much higher than the national average of 15.1% based on 2010 census data (US Census Bureau 2010). The study took place within West Baltimore in the relatively impoverished Franklin Square neighborhood and slightly higher income Union Square neighborhood. In addition to its lower socioeconomic standing, the life expectancy within Franklin Square is much lower than the Baltimore City average, and the neighborhood is replete with abandoned buildings (2011 Neighborhood Health Profile, Baltimore City Health Department). Though Union Square maintains a generally higher mean household income and a lower crime rate, the neighborhood still contains a number of abandoned buildings.

Urban decay also most notably alters the built environment within affected neighborhoods through the deterioration of buildings and the buildup of trash. Though mosquitoes may be found in higher-income neighborhoods where bird baths or children's toys may provide sufficient larval habitats, previous studies have shown that neighborhoods with low socioeconomic status tend to be associated with a higher prevalence of containers where mosquitoes can breed and lay eggs (Richards et al. 2008; Chambers et al. 1986). These containers often are discarded and unused trash that catch and contain rainwater. Despite many efforts to understand abiotic and biotic factors governing mosquito production, a lack of knowledge still exists in relation to these factors in urban areas, especially concerning adult prevalence. This information is crucial for successful mosquito control and public health efforts. Pest control efforts in Baltimore are underfunded and tend to only consist of low levels of larval control, and, in recent years, there have been no governmental mosquito control efforts within Franklin Square or Union Square (Pers. Comm., Shannon LaDeau). This project begins to more closely examine how the process of urban decay may alter mosquito production and composition. Specifically, I examined the potential of roofless abandoned buildings as urban mosquito breeding habitats in Baltimore, Maryland. Beyond being breeding habitats, I expected that the density of roofless buildings would also serve as an effective indicator of levels of urban decay within the neighborhoods.

Preliminary larval mosquito surveys found predominantly *Aedes albopictus and Culex pipiens* mosquitoes in Baltimore (LaDeau, Unpublished Data). Currently, Ae. albopictus is the most prevalent species of mosquito on the East Coast (Leisnham 2011). The Asian tiger mosquito, as it is typically called, was first introduced into the United States in the mid-1980s from East Asia and has since rapidly spread eastwards and northwards across the country (Benedict 2007). The mosquito was first discovered in Maryland in 1987 at a tire processing plant (Maryland Department of Agriculture, Date Unknown), and has been shown to be especially adept in utilizing a number of artificial water-holding containers for breeding. The species' daytime biting behavior, aggressive anthropophilic nature, and ability to live and reproduce in human-dominated landscapes have allowed it to become a major pest species in communities containing established populations (Hawley, 1988). In addition to being a nuisance, Ae. albopictus is an effective disease vector and is able to transmit a number of arbovirus, most notably dengue fever and chikunguya virus (Gratz 2004). On a community level, the competitive abilities of Ae. albopictus have led to altercations in mosquito composition as the species invades and spreads into previously uninhabited environments (Juliano and Lounibos 2005).

Cx. pipiens are found in all urban and suburban temperate and tropical regions throughout the world, where they typically serve as primary disease vectors (Farajollahi et al. 2011). Their large distribution is primarily attributed to the ability of the mosquitoes to utilize human-created environments with standing water containing high levels of organic content (Bockarie et al. 2009). The mosquito thrives in polluted sewers, mates in confined spaces, often enters houses, and tends to overwinter in basements (Eldridge 1987). In the United States and throughout most of North America, Cx. pipiens is considered to be the primary enzootic vector of West Nile virus. This is because of its ornithophilic feeding preference, high abundances, and high prevalences of WNV (Kilpatrick et al. 2005). In addition, Cx. pipiens may serve as bridge vectors due to their tendency to take a portion of their blood meals from mammals and humans (Farajollahi et al. 2011). Because of this, knowledge of their spatial distribution is important in predicting potential outbreaks of disease.

Previous studies have shown arbovirus emergence to be positively correlated with urban land-use (LaDeau et al. 2011), stressing the importance of knowledge regarding mosquito habitat usage within urban areas. In urban container habitats, primary productivity, predation, and shade all may play a role in determining larval density and survival to adulthood. Reiskind et al. have shown that varying leaf species in diet can significantly affect the larval survival of Ae. albopictus, and Costanzo et al. found that altering larval diet affected the competitive ability of Ae. albopictus over Cx. pipiens. (Reiskind et al. 2009, Costanzo et al. 2011). In isolated environments, mosquito predator density has been shown to decrease in abundance, allowing for greater survival of mosquitoes (Chase and Shulman 2009). Higher levels of shade have also been shown to allow for increased survival of some Aedes mosquitoes (Leisnham et al.

2007). Though these studies have examined factors relating to mosquito survival in laboratory, suburban, or rural settings, many have not been replicated within an urban matrix.

Because the insides of roofless abandoned buildings are likely to be shaded, isolated environments with collected rainwater and low trophic complexity, invasive mosquitoes may be able to achieve high levels of production with little interference from predators. Because of this, and because of prior studies displaying its role as a superior competitor, I expected to find *Ae. albopictus* to be the most abundant mosquito in Baltimore. Mosquito control efforts are typically focused on the emptying of container habitats and on larvicidal controls. However, these types of efforts do not address the potential breeding habitats within abandoned buildings. Due to safety risks and legal constraints associated with entering abandoned buildings, the only method of control may be government action to condemn and then demolish the entire structure. In addition, the density of these buildings may serve as an efficient approximation of urban decay, due to their concentration in low-income areas with high levels of physical deterioration. Data from this study regarding areas of increased mosquito production will add a new dimension to discussions of strategies for mosquito control within urban areas.

METHODS

Mosquitoes were collected over four days during late July and early August, 2012 in the Union Square and Franklin Square neighborhoods of West Baltimore. To account for potential temporal variation in abundance, mosquitoes were trapped for two days during the week of July 22, 2012 and two days during the week of July 29, 2012. Traps were typically set at 2 PM and collected the next day at 9 AM. CDC Light Traps and Biogents Sentinel traps were baited with CO_2 and placed next to each other in order to maximize efficiency in catching multiples species of adult mosquitoes. Traps were set on one Union Square block and one Franklin Square block daily, with two sets of replicates occurring per block on each trap day.

The two study blocks were chosen for their level of roofless abandoned buildings, with emphasis on finding representative extremes of high urban decay and low urban decay within the neighborhoods. The Union Square location was chosen as a control and contained low levels of trash and buildings generally in prime physical condition. In addition, many building occupants carefully tended to their property, and often created backyard oases through planting additional plants and greenery. In contrast, the Franklin Square location contained high levels of trash, a greater number of roofless abandoned buildings, and a vacant lot (Figure 1). The majority of homes on the Franklin Square block were completely deserted. The study blocks were located approximately 800 meters apart to minimize any effect of mosquitoes flying between the two study areas. Trap locations within the blocks were selected with attention paid to minimizing exposure to sunlight, wind, and rain to take into account previous studies that revealed that traps in exposed areas often collect fewer mosquitoes (Unlu 2011). Traps were placed in areas shaded fully by vegetation in both study areas. The traps were moved to various locations within the blocks between trap days in order to provide a more representative analysis of mosquito abundance and composition within the entire block, rather than providing a depiction of mosquito abundance and composition within one yard. Following collection, trap nets were labeled with date and trap number, and were transported on dry ice back to a lab. Mosquitoes were transferred to a freezer, counted, and identified by species. Temperature and precipitation data were obtained from the Baltimore Inner Harbor weather station.

To examine whether roofless abandoned building density served as a valid signifier of urban decay, I recorded the level of decay and the number of roofless abandoned buildings within approximately 100 meters of traps. Decay was categorized as being high, medium, or low at each trap site based upon levels of trash and general physical conditions of all buildings observed within 100 meters. Areas containing clearly deteriorating buildings and excessive amounts of trash scored “high,” whereas sites with buildings in prime physical condition and scarce amounts of trash scored “low.” The number of roofless abandoned buildings was then counted using a combination of aerial images and on-foot observation.

RESULTS

Overall, 1169 mosquitoes were collected over four days, of which 588 were female *Ae. Albopictus* (52.3%). Although BG-Sentinel traps are designed to catch blood-seeking females, 549 male *Ae. albopictus* were caught (48.8%). Other species caught included *Culex pipiens, Aedes vexans, Ochlerotatus cantator,* and *Ochlerotatus sollicitans* (Figure 2).

Statistical analyses were concentrated upon female *Ae. albopictus* abundance due to their status as bridge vectors and nuisance biters, and due to the insignificant levels of other trapped mosquitoes. During Week 1, an average of 32 more female mosquitoes per trap were found on the less degraded Union Square block (Poisson test, $p < .001$) and during Week 2, an average 80 of more female mosquitoes were found per trap on the Union Square block (Poisson test, $p < .001$) (Figure 3).

In addition, density of roofless abandoned buildings within blocks does seem to serve as an effective approximate indicator of urban decay (Figure 4). A total of 10 observations recorded over the two weeks produce a roughly positive correlation between symptoms of urban decay and roofless abandoned buildings closely surrounding the trap site.

DISCUSSION

Consistent with expectations, results showed *Ae. albopictus* to be the most dominant mosquito species in Baltimore. However, contrary to expectations, the results suggest that higher levels of mosquito production occurred in the higher-income Union Square block than in the lower-income and less decayed Franklin Square block. These results, in combination with data gained from a simultaneously occurring study on larval habitat within the two neighborhoods, may suggest a few possible causes behind the unexpected outcome.

Preliminary results from the larval habitat study displayed both a higher level of containers and a higher level of larval presence within the lower-income Franklin Square neighborhood during June 2012 (LaDeau, unpublished). This initial June sampling did not occur on blocks sampled for adults during my study, however, it did occur on comparable blocks closely bordering my study areas. In August 2012, larval sampling was specifically focused upon the two blocks observed during my study, and revealed only 9 water-collecting containers on the Franklin Square block, and 21 water-collecting containers on the relatively higher-income Union Square block. Only 4 of the 9 containers in Franklin Square contained mosquito larvae, while 10 of the 21 found in the Union Square block contained larvae. These results differ from previous studies showing lower income areas to contain both higher numbers of larval habitats and higher levels of positive containers (Chambers et al. 1986). In addition, trends in these data differ from trends observed earlier in the summer, showing Franklin Square to be the area containing higher larval presence.

Data on adult abundance gained from my study may suggest a higher level of mosquito production within the higher-income block in late summer, as compared to a lower level of production in early summer. This pattern may be attributable to a few causes; namely variation in temperature throughout the summer and container heterogeneity across neighborhoods. June 2012 had an average temperature of 23.11 °C; July had an average temperature of 27.44 °C; and, August had an average temperature of 26.5 °C (NOAA, 2012). Commonly, the types of containers found in Franklin Square were smaller articles of trash, such as empty Styrofoam cups or discarded plastic bags, whereas the types of containers found in

Union Square were larger, such as buckets and empty planters (LaDeau, unpublished). These larger containers are more likely to hold water throughout the summer, in contrast to smaller containers that allow water to evaporate in hot late-summer temperatures. Barlett-Healey et al. showed that trashcans contain standing water for up to 40 days, while snack bags tend to contain water for only 8 days. They further show that trashcans and planters are particularly effective habitats for *Ae. Albopictus* (Bartlett-Healy et al. 2012), which is consistent with the results found in my study. In addition, the Union Square block was more heavily shaded due to additional planting of foliage and a generally higher level of upkeep. This higher level of upkeep often was associated with potential larval habitats such as birdbaths, trashcans, and buckets used for watering plants. The shade in these backyards may have allowed containers to stay cooler, and might have allowed for higher retention levels of water throughout the summer. Additionally, the shade provides a food source for mosquito larvae as leaves and debris fall and collect in containers (Eaton et al. 1973). Past studies have shown that *Ae. albopictus* prefer to oviposit in containers with leaves (Dieng et al. 2003) and that *Ae. albopictus* development may be enhanced by containers with leaf litter, in turn leading to higher adult production (Juliano and Lounibos 2002). The Franklin Square block contained little to no additional planted vegetation, and yards generally received more sunlight than yards in Union Square. The results point towards vegetation and shade being highly important in determining levels of mosquito production, however more advanced spatial analyses must be completed to fully quantify these findings.

While analyzing degraded urban landscapes spatially, roofless abandoned buildings do tend to act as an accurate metric on determining of levels of decay, however more replication in a variety of locations is needed to justify this finding. This metric is useful in that aerial images containing images of roofless buildings can act as effective tools in approximating levels of urban decay and degradation within cities. Previously, levels of decay have only been able to be approximated using on-site knowledge. As detailed aerial imagery becomes increasingly available, knowledge of signifiers of decay can be useful in remotely assessing symptoms of decay. However, I found no significant evidence showing that these roofless buildings act as sites of increased of mosquito production. Further studies must be completed throughout the late spring and early summer to fully analyze their role as exceptionally productive larval habitats. In periods of higher rainfall than late summer, these buildings may prove to pockets of increased mosquito abundance.

Though purely speculative, my findings help provide clues as to the mechanisms by which human behavior can alter mosquito ecology within an urban matrix. The combination findings from my study with the findings of the larval sampling study have proven to be useful in helping to piece together clues regarding spatio-temporal variation in both larval and adult abundance of *Ae. albopictus* mosquitoes. Because larval presence is correlated with levels of adults, studies examining both larval habitats and areas of increased adult abundance are important in effectively concentrating mosquito control efforts effectively (Richards et al. 2008). Furthermore, studies examining mosquito production must simultaneously pair larval habitat analysis with adult mosquito abundance data throughout the entire mosquito season to present the most comprehensive analysis. Studies also must take into account the variety of factors that influence urban mosquito abundance which may have previously been ignored, such as vegetation, shade, resident knowledge of mosquito ecology, and the heterogeneous nature of container habitats. Future studies in Baltimore will concentrate upon developing effective mosquito control efforts within Franklin Square and Union Square, with an emphasis on bottom-up mosquito control through resident education. Although my study is preliminary in nature, it begins to suggest areas in Baltimore where concentration upon mosquito control may be necessary, and helps further illuminate the heterogeneous nature of urban adult and larval mosquito habitats.

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APPENDIX

FIGURE 1. Aerial photos c. 2010 of the Union Square block (left) and the more heavily decayed Franklin Square block (right). Yellow pins represent roofless abandoned buildings. In 2010, the Union Square block contained 1 roofless abandoned building and the Franklin Square block contained 15 in total. Images taken from Google Earth.

	Ae. albopictus	Male *Ae. albopictus*	*Cx. pipiens*	*Ae. vexans*	*Oc. sollicitans*	*Oc. cantator*
Union Square Week 1	149	39	8	0	0	0
Franklin Square Week 1	61	41	4	1	0	0
Week 1 Total	210	80	12	1	0	0
Union Square Week 2	351	442	16	0	1	1
Franklin Square Week 2	27	27	1	0	0	0
Week 2 Total	378	469	17	0	1	1
Overall Total	588	549	29	1	1	1

FIGURE 2. Summary of mosquito species trapped over the course of the study. Invasive *Ae. albopictus* composed the large majority of captured mosquitoes in the study.

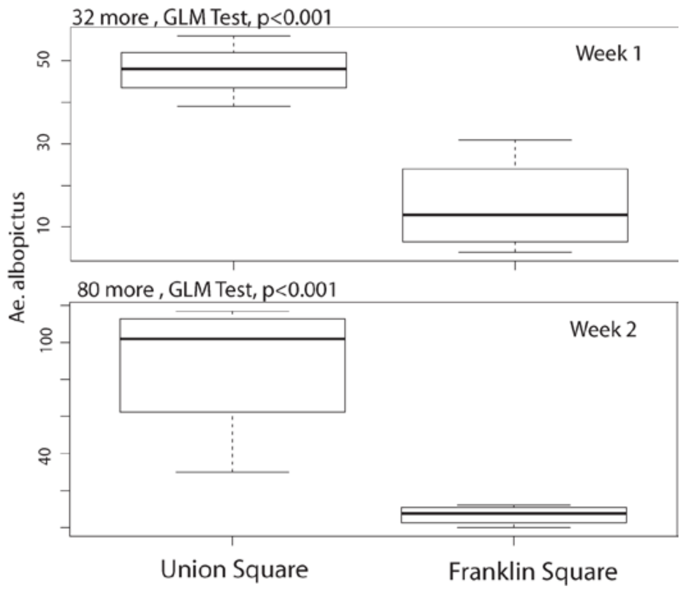

FIGURE 3. Box plot displaying median values of female *Ae. albopictus* caught on the study blocks during Week 1 and Week 2. Significantly more *Ae. albopictus* were found on the Union Square block during both weeks of trapping. Generally higher levels of total *Ae. albopictus* were found on both blocks during Week 2.

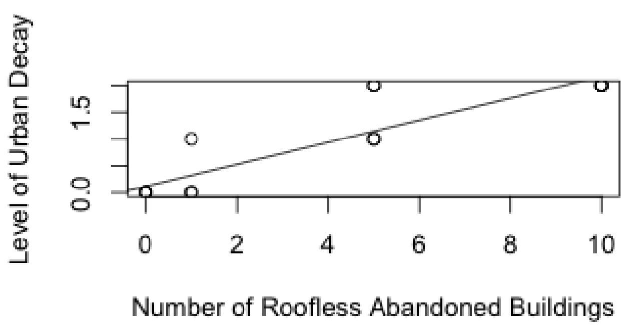

FIGURE 4. Relationship between roofless abandoned buildings and general level of urban decay with line of best fit. Higher levels of urban decay were positively associated with the number of roofless abandoned buildings within 100 meters of the trap location.